Inquiry: The University of Arkansas Undergraduate Research Journal

Volume 13 Article 4

Fall 2012

Northwest Arkansas Comprehensive Environmental Analysis and Regional Smart Growth Plan

Nick Cerra
University of Arkansas, Fayetteville

Zac Prange
University of Arkansas, Fayetteville

NORTHWEST ARKANSAS COMPREHENSIVE ENVIRONMENTAL ANALYSIS AND REGIONAL SMART GROWTH PLAN

By Nick Cerra & Zac Prange

Faculty Mentor: Dr. Noah Billig
Department of Landscape Architecture

Abstract

For the past two decades, Northwest Arkansas has experienced rapid growth and increased urban development; population projections see the continuation of these trends (Wiley, 2010). Environmental conditions in the study area make it particularly sensitive to the effects of urban development, while existing landscape hazards and nuisance land uses jeopardize the quality of the urban form. Despite these phenomena, there is no comprehensive land use analysis or development management plan for Northwest Arkansas. This study presents a comprehensive environmental analysis of three sub-watersheds within the Illinois River watershed in Northwest Arkansas. Based on this analysis, the authors recommend planning overlays for future development and preservation in the Clear Creek, the Osage Creek, and the Illinois Headwaters sub-watersheds. This study fills the gap in Northwest Arkansas' development strategy by recommending watershed level management and development priorities and practices. The regional environmental planning framework provides the comprehensive nature of the analysis used to determine these policies. This study goes beyond the merely normative process of citing new growth, however, by connecting sound planning policy to current research suggesting that Best Management Practices (BMPs), Low Impact Development (LID), and Smart Growth will provide the means necessary to sustain a high quality of life in Northwest Arkansas.

Introduction

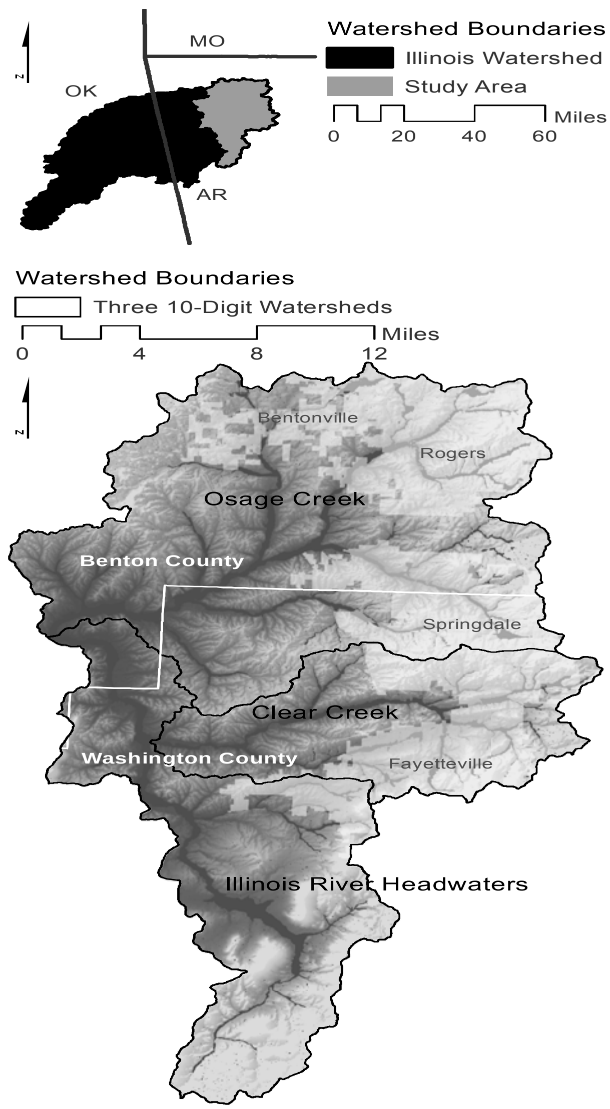
Northwest Arkansas is home to one of the fastest growing economies in the country. However, lack of a comprehensive regional development strategy and recent global economic downturns jeopardize this strength (Market Street Services Incorporated, 2011). The Northwest Arkansas Council represents regional business leaders and is a proponent of quality economic growth. Many area stakeholders are involved in an ongoing process to decide the future of Northwest Arkansas. Market Street Services Incorporated contributes to this discussion through its recent preparation of the Northwest Arkansas Regional Development Strategy. The strategy outlines a plan for guiding economic growth in Northwest Arkansas and calls for a holistic community development strategy (Market Street Services Incorporated, 2011).

At the heart of any plan for sustainable economic growth are environmental planning policies that ensure the right balance of economic feasibility, ecological integrity and social justice. By balancing all three of these factors, economies produce real, sustainable income, or that which does not come at the cost of spoiling natural or cultural resources (Hawken, 2009). Only a comprehensive environmental analysis can provide the holistic understanding needed to create a sustainable land use plan for Northwest Arkansas.

Northwest Arkansas is a developing economic region with a history of agricultural production that once dominated the landscape. The region's rural economic roots are superseded, however, by the recent "creation, growth, and success of multiple corporate headquarters" (Market Street Services Incorporated, 2011). The Clear Creek, Osage Creek, and the Illinois

River Headwaters are three of 12 sub-watersheds within the greater Illinois River watershed. They are of particular interest because they contain the main tributary streams of the Illinois River and because much of the projected development in Northwest Arkansas lies within their boundaries.

This study will develop a framework for land use decisions within the Clear Creek, the Osage Creek, and the Illinois River Headwaters watersheds. The city limits of Bentonville, Rogers, Springdale, and Fayetteville partially lie within these three sub-watersheds. These cities are located in the easternmost portion of the study area, positioned on a north-south corridor that straddles the source of the three tributaries (see Figure 1).



Cultural data source: ESRI, Tele Atlas North America, Inc., Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), United States Central Intelligence Agency. LIDAR data source: Northwest Arkansas Regional Planning Commission (2005).LULC Data Source: Center for Advanced Spatial Technologies (2006).Watershed data source: U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency, USDA Forest Service (2009, 2002).

Figure 1. Mapping the Hydrologic Unit

Development is the main factor affecting the future of the Illinois River watershed. For the last two decades, this area has experienced rapid growth and increasing urbanization. The 2010 census estimated this area’s population to be 463,000 - a 34%increase from 2000 (Wiley, 2010). A 2010 report produced by the University of Arkansas Little Rock Institute for Economic Advancement projects the 2020 population to increase by 50% in Benton County and 32% in Washington County (Wiley, 2010). Much of this development is pushing west from the five largest municipalities in the Osage Creek, Clear Creek and Illinois Headwaters watersheds.

The central and western portions of the study area link to Northwest Arkansas’ rural history and are primarily composed of pastureland, scattered low-intensity development, and fragmented deciduous forest. The poultry industry has a large presence in the area, and is a holdover from the agrarian past. As with all concentrated animal operations, poultry farms cause property values to drop and compete for land use with the spread of urbanization (White, 2000). The most noticeable accessory of this agrarian land use in Northwest Arkansas is the Confined Animal Feeding Operation (CAFO) - colloquially known as “chicken houses”. The central and western portions of the study area are home to over 1000 poultry CAFOs. The EPA has identified the “regional clustering” of poultry CAFOs in Benton and Washington Counties as a potential source of ground water contamination, and has identified numerous water bodies that have been impaired by the surface application of manure (Beardsley et al., 2008). USDA officials have acknowledged the problem and counter that nutrient management programs have reduced the impact of manure spreading, but have yet to “provide information on the extent to which these techniques are being utilized or their effectiveness in reducing water pollution from animal waste” (Beardsley et al., 2008, p. 28).

Water contamination susceptibility, both at the surface and below ground, is a major concern in the study area (for more reasons than just the regional clustering of CAFOs). Most of the study area lies on top of large geologic concentrations of readily dissolvable limestone and receives over 40 inches of rainfall per year. These two factors combine to create karst topography, where the dissolution of limestone produces permeable bedrock. Karst is “a unique hydrogeology that results in aquifers that are highly productive but extremely vulnerable to contamination” (Department of the Interior, 2012, p. 1). Karst areas produce 40% of the groundwater used for drinking in the United States (Department of the Interior, 2012).

Urbanization pressures, agricultural land uses and sensitive hydrogeologic processes require careful study. The Surface Water Contamination Susceptibility and Ground Water Contamination Susceptibility maps (see Figures 2 and 3) compile and analyze environmental factors including land use and land cover, hydrogeology, biosphere sinks and buffers, and a myriad of soil characteristics. These maps provide evidence of water contamination susceptibility in the three sub-watershed area and reveal the importance of forested areas for protecting water quality.

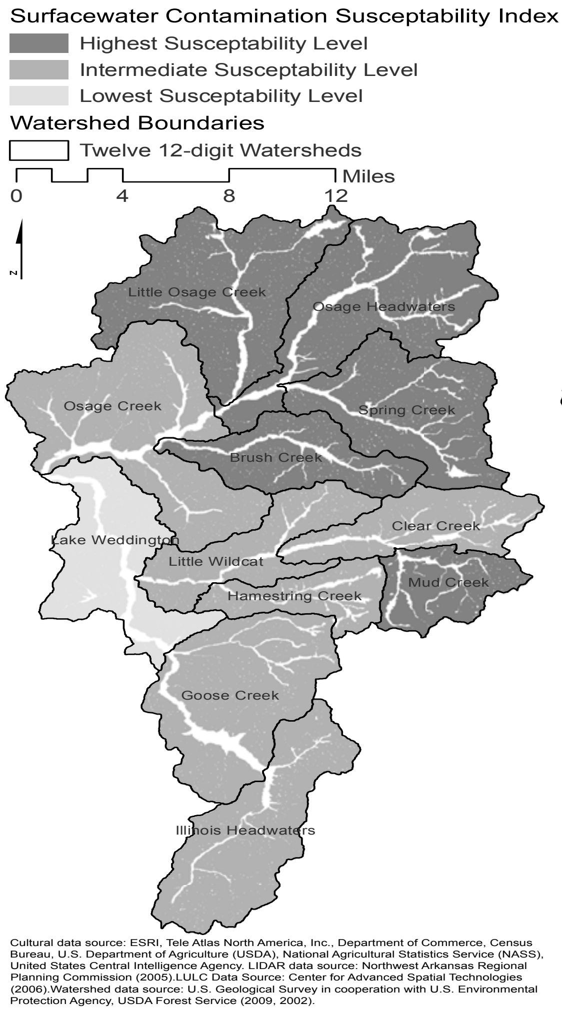


Figure 2. Surfacewater Contamination Susceptability Index

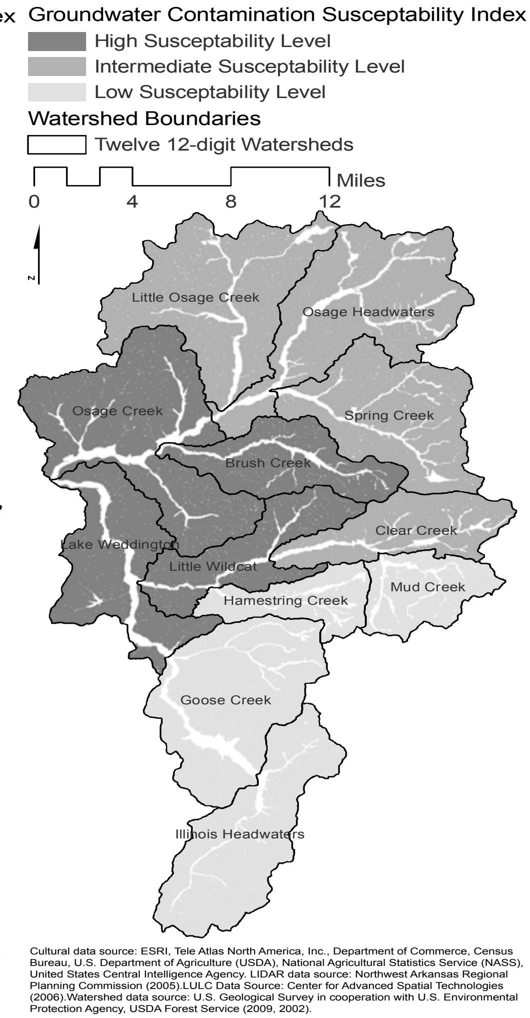


Figure 3. Groundwater Contamination Susceptability Index

The study area was historically home to a variety of rich and diverse ecosystems. Woodlands, prairies, and wetland forests once dominated the landscape; today only fragments are reestablished. Most of the high quality forest habitat existing today lies in western and southern portions of the Illinois Headwaters watershed. Forested areas in the Osage Creek and Clear Creek watersheds exist predominantly as small fragments separated by roads and pastureland. Since little of the indigenous habitat remains in the study area, a portion of the analysis identifies high quality forest patches for preservation and recommends carefully sited areas for reforestation (see Figure 4).

Human factors further classify areas for development suitability. Many locations in the region are inherently unsuitable for development due to hazardous or undesirable environmental conditions, while certain elements of the human environment have the ability to incentivize growth. The study area is also rich in natural resources important to humans. These include scenic amenities, extractive resources, and soils of high agricultural value. Avoiding locations susceptible to the hazards of floods and landslides can prevent property damage and loss of life. A soil's limitation for construction purposes is also important to consider since building on waterlogged soils and steep slopes is difficult and costly. New development should take advantage of established infrastructure within the existing grid, where connections are less costly. Concentrating development around existing infrastructure also leads to better connectivity, the lack of which is as an economic obstacle in the region (Market Street Services Incorporated, 2011).

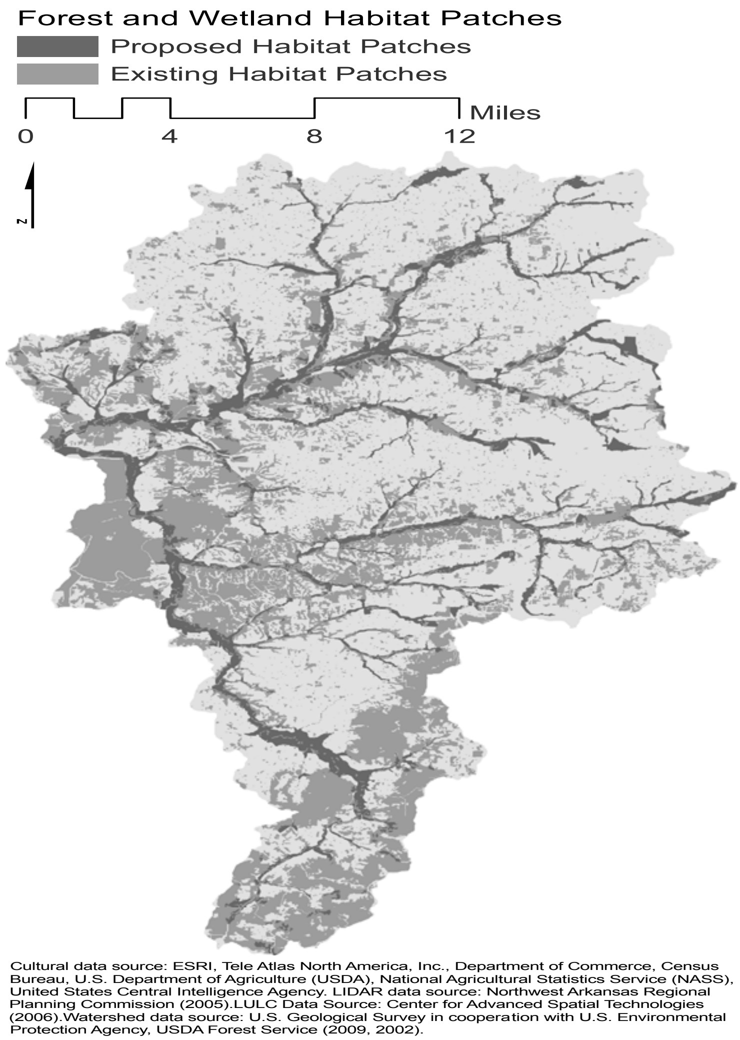
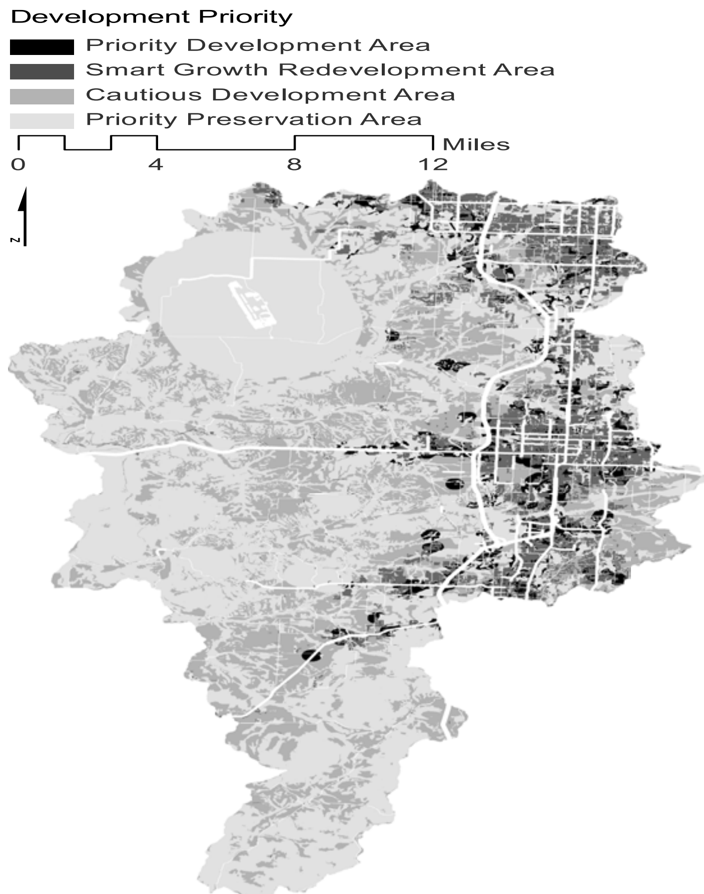


Figure 4. Creating New Habitat

The final section of the study identifies development priority areas and makes recommendations for future growth based on these distinctions (see Figure 6). The five analysis subcategories of Assessing the Hydrological Unit, Surface Water Quality, Ground Water Quality, Habitat Quality, and Human Factors provide a basis for determining development priority overlays. This development plan provides ample space for growth while protecting and improving our natural and cultural resources.

As growth increases in Northwest Arkansas, so does the importance of implementing management and development priorities and practices. Environmental changes caused by development and the spread of urban areas result in severe and costly environmental impacts. Such impacts reduce property values, degrade ecosystems, and affect human health. Protecting our natural and cultural resources will not only help maintain Arkansas' natural scenic beauty, but it will also help the local economy continue to flourish by increasing property values, preserving scenic interest, and preventing future reparations.



Cultural data source: ESRI, Tele Atlas North America, Inc., Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), United States Central Intelligence Agency. LIDAR data source: Northwest Arkansas Regional Planning Commission (2005).LULC Data Source: Center for Advanced Spatial Technologies (2006).Watershed data source: U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency, USDA Forest Service (2009, 2002).

Figure 6. Development Priority Plan

The plan outlined by the Northwest Arkansas Development strategy is clear: a concentrated investment in regional economic cooperation and the development of better-connected infrastructure and regional transit will bring prosperity to Northwest Arkansas (Market Street Services Incorporated, 2011). Regional growth and a need for well- developed, better-connected infrastructure likewise creates the impetus for studies in regional environmental planning. For example, one Minnesota based study that seeks to “guide the form and location of new development in a way that protects natural resources and builds livable communities” (Bolan et al., 2002, p. 1) takes a watershed approach to regional Smart Growth planning. Watershed level planning within the regional environmental planning framework is a way to bring sustainable growth to the region and to ensure that the goals of the Northwest Arkansas Development Strategy are within the current resource potential.

A comprehensive environmental analysis will provide the holistic understanding needed to create a sustainable land use plan for the future of Northwest Arkansas. This study evaluates a broad spectrum of environmental factors to produce an analysis of the study area. The study’s five main analysis sections include: Assessing the Hydrologic Unit; Surface Water Quality;

Ground Water Quality; Habitat Quality; and Human Factors. The final Development Suitability plan builds on the composites produced in the analysis portion of this study and refers to recent recommendations of the Illinois River Watershed Partnership and the Northwest Arkansas Council. In this final map, planning overlays represent areas where the implementation of development incentives and/or restrictions shall responsibly guide future growth. The recommendations section of this study outlines these planning overlays and explains their implications for growth in the study area.

Analysis

The Hydrologic Unit

The three 10-digit watersheds within the study area are identified in Figure 1. Surface water and groundwater contamination susceptibility composites are created by combining data within each 12-digit sub-watershed (see Figures 2 and 3). This allows a contamination susceptibility rating to apply to each 12-digit unit. For this study, the watersheds divide into three components: bottomland sinks, upland areas, and transitional buffers.

Bottomland sinks include perennial streams and adjacent low-elevation areas subject to seasonal flooding. This is where water ultimately accumulates from the higher elevations. Incidentally, this is where most contaminants such as agricultural pollutants and sediment accumulate and become concentrated. In this study, bottomland areas delineate by identifying the banks of perennial streams and 100-year floodplains. Bottomland accounts for 22,000 square acres of the study area.

Upland accounts for 91% of the study area and includes all areas outside of the bottomland sinks. These areas drain into streams and are the source of contaminants that accumulate in bottomland sinks. Disruptive land use practices in the upland include agriculture, forestry, industrial development, and human settlement that alter the natural landscape and cause an increase in contaminants. Land use changes in the upland directly affect surface and groundwater quality.

Transitional buffers delineate a 33-meter wide zone bordering all bottomland sinks in the study area (Schueler, 1995). These buffers provide a filter zone to intercept contaminants before they reach the bottomland sinks. Vegetation within the transitional buffer captures contaminants and reduces the occurrence of erosion by slowing the velocity of runoff from the upland. The transitional buffer’s capacity to remove contaminants relies on the presence of vegetation and minimal disturbance. For this reason, development here is avoided.

Surface Water Contamination Susceptibility

In order to determine each hydrologic unit’s susceptibility to surface water contamination, three factors are delineated and contamination risk values assigned. These factors are Contaminant Source Intensity, Buffering Capacity, and Hydrologic Unit Resiliency. A composite map addressing surface water contamination susceptibility within each of the 12-digit sub-watersheds is created from these three factors (see Figure 2). The 12-unit watersheds are ranked as having Low, Medium, and High susceptibility based on the range of values within the study area (Bolan et al., 2002).

Contaminant source intensity. Contaminant Source Intensity for each 12-digit watershed is established by combining three factors: the presence of erosion-prone soils, hydrologically restricted soils, and disruptive land cover types in upland areas. By combining these factors, a ratio of contaminant intensity per 12-digit watershed is developed.

Erosion prone soils are directly related to slope, soil fragility, runoff potential, and land use. The Ozark Mountain region consists of steep, hilly terrain with localized concentrations of fragile soils. The high clay content of soils in the study area contributes to runoff potential. Disruptive land uses cover much of the study area.

Slope increases the velocity of storm water runoff, which dislodges more sediment. In order from low to high erosion, slope classes are as follows: < 3%, 3 - 6%, 6 - 12%, > 12% (Soil Survey Division Staff, 1993).

Soil fragility creates soils that are easily carried off by storm water. Areas with fragile soils are identified based on their rating in the U.S. Natural Resources Conservation Service soil data set. Soil types "C" and "D" are identified as having high erosion potential and are inventoried in this analysis (Soil Survey Division Staff, 1993).

Runoff potential is high in the study area due to certain soil characteristics. Class "C" soils have a slow infiltration rate when thoroughly wet, and Class "D" soils have a very slow rate of infiltration. They consist primarily of clays, and often exist as a very thin layer above an impervious layer or high water table. Hydric Soil Groups further classify runoff potential. This system divides soil types into four categories by their estimated runoff potential. Runoff potential is approximated by assessing the rate at which water infiltrates when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-term duration storms (Soil Survey Division Staff, 1993).

Land Use has a significant contribution to erosion, and Land Use/Land Cover (LULC) data identify areas that contribute significantly to contamination. Land cover types identified as disruptive include: barren land, pastureland, cultivated crops, and developed land. Pastureland is categorized as disruptive in the study area due to its contribution to suspended sediment (Randolph, 2004).

Buffering capacity. Buffering Capacity has an enormous effect on overall Surface Water Contamination Susceptibility. The capacity for transitional buffer zones to prevent contaminants from reaching bottomland sinks relies on the type of land cover that lies within their boundaries. Land cover types that maximize a buffer's filtering capacity include transitional scrubland, native grassland, and all forest cover types (Schueler, 1995). The areas of land cover within transitional buffer zones that are capable of providing filtration are aggregated into a single value. This is done by combining Land Use/Land Cover (LULC) data with the transitional buffer area established through a Geographic Information System (GIS) analysis. The buffering capacity is determined by calculating the ratio of filtering groundcover to the total area of transitional buffer within each 12-digit sub-watershed.

Hydrologic resiliency. Hydrologic Resiliency is the ratio of sink area to the total area of each 12-digit sub-watershed. Hydrologic units with a higher ratio of sink area experience a lower concentration of contaminants due to dilution. Inversely, contaminants become more concentrated where less sink area is available.

By combining all of the aforementioned data sets, each of the 12 digit sub watersheds is ranked based on its susceptibility to surface water contamination (Bolan et al., 2002). Each of the three factors is weighted according to its importance using the following formula: Composite water contamination susceptibility = 2 * (Resiliency index) + 4 * (Buffering capacity) – 5 * (Source intensity index).

Groundwater Contamination Susceptibility

In order to determine each hydrologic unit's susceptibility to ground water contamination, four factors are delineated and contamination risk values assigned. These factors are soil depth, bedrock permeability, slope, and soil percolation rate. A composite addressing groundwater contamination potential within each of the 12-digit sub-watersheds is created from these factors.

Soil depth over the study area is divided into three categories: Thin, Medium, and Thick. The Washington County Soil Survey determines these categories (Haley, Harper, & Phillips, 1969). Hydrologically restricted soil groups C and D are classified as thin regardless of their “depth from surface” classification due to excessive runoff and lack of contaminant filtration (Aller, Bennett, Lehr, Petty, & Hackett, 1987; Haley et al.,1969). The soil depth categories are as follows: Thin < 20 inches, Medium = 20 – 40 inches, and Thick > 40 inches.

Bedrock permeability in the study region is divided into two main types by material: area consisting predominantly of limestone and area consisting predominantly of sandstone. Bedrock consisting primarily of limestone is determined to have a high rate of permeability, while that consisting predominantly of sandstone has a moderate permeability rate (Aller et al., 1987; Gleeson et al., 2011). Each type is rated based on permeability: predominately limestone = high permeability – 3, predominately sandstone = moderate permeability – 2.

Slope contributes to a soil’s ability to remove contaminants. Flat land increases the risk of groundwater contamination by increasing infiltration, while steeper slopes significantly reduce this risk (Aller et al., 1987). The study region is divided into three weighted categories based on infiltration rate: High < 8% slope = 3, Moderate 8 - 12% slope = 2, Low > 12% slope = 1.

Percolation rates in the study area are divided into two groups based on hydrologic restriction. C and D soils have low infiltration rates while class B soils are rated moderate (Aller et al., 1987). Weights are assigned based on contamination risk. The two categories are as follows: Low - C & D soils = 2, Moderate – B soils = 1.

The four aforementioned factors are combined and weighted based on a modified DRASTIC method. The Environmental Protection Agency (EPA) describes the DRASTIC method as a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value for groundwater pollution potential. The DRASTIC name is an acronym drawn from the factors of: depth to aquifer, net recharge, aquifer media, soil media, topography, impact of the vadose zone, and hydraulic conductivity of the aquifer (Aller et al., 1987). For the purposes of this analysis, these factors and their corresponding values are obtained from the Washington County, Arkansas soil survey (Haley et al., 1969). These surveys contain the necessary data for analysis, but combine several of the DRASTIC factors. The DRASTIC method is modified to acknowledge this combination. Modified DRASTIC ratings are divided into three categories to create a groundwater contamination susceptibility index. Each 12-digit sub-watershed is assigned a rating of low, medium, or high susceptibility.

Habitat Quality

Forest habitat. Three health indicators of forested areas are compiled in order to determine the quality of forested habitat patches within the study area: forest patch size, forest patches by percentage of core, and forest patches including a mix of habitats. Each of these factors is compiled in a Composite Habitat Quality Rating for all forested patches within the study area. This rating is based on quality values assigned to each of the first three factors. A Washington County, Minnesota regional environmental analysis provides a precedent for the combination of these factors (Bolan et al., 2002). Spatial analysis creates a hierarchical composite rating.

Analysis of habitat quality based on the three aforementioned factors creates a general understanding of habitat quality. Since each of these three factors contributes independently to overall quality, a quality rating is saved for the final composite. The patches are weighted based on the values used in the Washington County, Minnesota analysis (Bolan et al., 2002). Combining the weighted values creates an understanding of individual patch health.

Forest patch size is a key indicator of overall habitat quality and works on a relatively simple principle - the more surface area covered by continuous forest, the greater the potential for habitat. Patch sizes smaller than 2.5 acres are known to possess little value as species habitat, while patches larger than 2.5 acres support more species diversity (Dramstad, Olson, & Forman, 1996). In this index, patches of forest are categorized by their total size. This index records whether a forest patch has the size necessary to support substantial biodiversity. Forest patch size falls into two categories: < Or = 2.5ac are rated 1, > 2.5ac are rated 2.

The existence of a large percentage of core forest inside a forest patch is another indicator for habitat quality. Forest areas isolated from human disturbance are more capable of supporting sensitive species. Areas inflicted by environmental disturbance select for only the most tolerant species and deter those that thrive in exclusion from human activity. Because of this, the functional habitat area of a forest is reduced by a measurable amount. To determine core areas, forest patches were buffered by 328 feet (100 meters) from all human disturbance areas (Bolan et al., 2002; Dramstad et al., 1996). Forest patches with large core percentages inside of this buffer zone are considered to be of a higher quality. In the index, forest patches are rated based on the percentage of "core" area they contain (Bolan et al., 2002; Minnesota Department of Natural Resources, 2003). Percentage of forest core falls into the following two categories: patches with < 40% core are rated 1, patches with > Or = 40% core are rated 2.

Forest patch quality is further increased by the existence of multiple physiographic distinctions within the patch. For this index, the authors have distinguished bottomland and upland areas as separate physiographic categories. Each of these land cover types is able to support a unique ecological diversity. Therefore, forest patches that contain both of these habitat types are considered to be of a higher habitat value. This index rates forested areas based on whether or not they contain more than one habitat type (Bolan et al., 2002; Dramstad et al., 1996). Existence of a mix of habitats falls into the following two categories: areas with only one type are rated 1, areas with two types are rated 2.

To create a composite habitat quality index, forested habitat patches are rated based on their ability to support a diverse and sustainable ecosystem. Each of three factors (forest patch size, forest patches with large core size, and forest patches including a mix of habitats) combines to create this index. These values, however, are not considered to have equal contributions to habitat quality. Therefore, a final weighting is applied to the aggregated values for each forest area. The Composite Habitat Quality Rating uses the weighting values determined by the Washington County Land Use study (Bolan et al., 2002).

Wetland forest habitat. Another key indicator of habitat quality is the existence of wetlands. Wetland types in the study area include floodplain depressions, sinkholes, livestock ponds, and uncommonly, mountaintop depressions. High-quality wetland habitats support complex and biologically diverse ecosystems, especially when paired with other habitats (Arkansas Multi-Agency Wetland Planning Team, 2001). Patch sizes smaller than 2.5 acres are known to possess less value as species habitat whereas patches larger than 2.5 acres support more species diversity. In this index, wetlands are categorized by their total size. This index records whether a wetland area has the size necessary to support substantial biodiversity (Bolan et al., 2002).

Critical habitat. The study area is home to several federally protected and endangered animal and plant species. Such species are assigned a Natureserve endangered species rating based on the conservation priority for each. They are ranked on a scale of S1, meaning critically imperiled, to S5, or secure. Nine animals and one plant in the study area with S1 and S2 rankings are identified. Species and their rankings are as follows (U.S. Fish and Wildlife Service, 2012):

S1: Ozark Cavefish (Amblyopsis rosae)
Ozark Big-Eared Bat (Corynorhinus townsendii ingens)
Neosho Mucket (Lampsilis rafinesqueana)
Cave Crayfish (Cambarus aculabrum)
Indiana Bat (Myotis sodalis)
Arkansas darter (Etheostoma cragini)
Missouri Bladderpod (Physaria filiformis)

S2: Gray Bat or Gray Myotis (Myotis grisescens)
Rabbits foot (Quadrula cylindrica)
Bald Eagle (Haliaeetus leucocephalus)

Specific habitat areas and types required for sustaining healthy and stable populations of the aforementioned species are identified. The three primary special habitat types as well as the Logan Cave ecosystem are listed below with their respective species.

Riparian forest habitat is delineated by identifying forest areas located in bottomland sinks and adjacent to water. Urban and agricultural development has caused a substantial decline and fragmentation of this important habitat, which is the primary feeding ground for C. townsendii ingens, M. sodalis, and M. grisescens. It is the choice nesting habitat for H. leucocephalus and M. sodalist (U.S. Fish and Wildlife Service, 2012).

Perennial streams are essential to sustaining populations of the two mussels and one fish species. Populations have experienced a rapid decline due to alteration of stream corridors, surface water pollution, and sedimentation. E. cragini is particularly sensitive to groundwater pollution, because it favors perennial spring-fed streams (AR Natural Heritage Commission, 2010).

Cedar glades occur in upland areas where limestone bedrock occurs near the surface. This habitat is characterized by very shallow soil and occasionally exposed bedrock. It is the primary habitat for P. filiformis (AR Natural Heritage Commission, 2010).

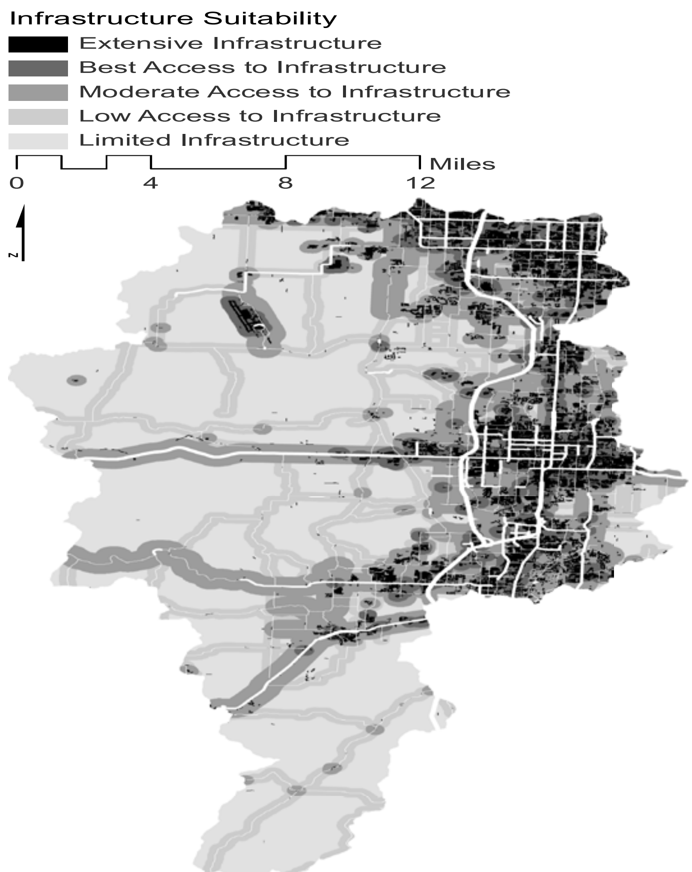
Logan Cave National Wildlife Refuge consists of 123 acres of protected land in the westernmost portion of the Osage Creek watershed. It includes a limestone-solution cave and a diverse habitat representative of several Ozark karst formations. The Logan Cave ecosystem is described as the highest quality cave habitat in the entire Ozark region (U.S. Fish and Wildlife Service, 2012). It also supports one of only two known populations of C. aculabrum as well as populations of M. grisescens and A. rosae (Jacobson, 1996).

Proposing New Habitat

Proposing new habitat is an important step in the protection of endangered species, and providing overall habitat quality. New habitat will improve the quality of existing forest and increase biodiversity within the study area. A thorough analysis of existing habitat conditions is completed using the forest habitat, critical habitat, and wetland forest habitat datasets. This information provides a solid understanding of regional habitat conditions. Goals for creating new habitat include increasing (a) connectivity between patches, (b) core size, (c) patch size, and (d) overall habitat quality. These goals are integrated into the future land use plan by including landscape ecology principles (Dramstad, 1996).

Human Factors

Three categories of human factors contributing to development suitability are compiled in order to produce a holistic understanding of land use constraints and opportunities in the study area. The spatial distributions of existing natural resources important to humans, landscape hazards, and intrinsic suitabilities for development are considered in this analysis. The aforementioned factors are compiled using a Geographic Information System (GIS) software suite known as ArcGIS version 10. The Intrinsic Suitabilities for Development map has been included (see Figure 5). Plotting the spatial distribution of these factors helps to discover the existing human environment's contribution to future land use.



Cultural data source: ESRI, Tele Atlas North America, Inc., Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), United States Central Intelligence Agency. LIDAR data source: Northwest Arkansas Regional Planning Commission (2005).LULC Data Source: Center for Advanced Spatial Technologies (2006).Watershed data source: U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency, USDA Forest Service (2009, 2002).

Figure 5. Infrastructure Suitability Plan

Natural resources important to humans. When determining natural resource values, existing spatial qualities are inventoried and assessed based on their ability to function as a resource. Two factors (Raw Natural Resource Value and Natural Resource as Amenity) are herein considered. These values are not weighted to provide an index for suitability as with previous portions of the study; however, their inclusion provides a better understanding of development suitability in the Clear Creek, Osage Creek and Headwaters watersheds.

Soil qualities and extractive resources are considered as raw resource values. Soil class, as determined in the Washington County Soil Survey, rates a soil's agricultural production value (Haley et al., 1969; Soil Survey Division Staff, 1993). The lower a soil's class number, the more valuable it is for agricultural production (Soil Survey Division Staff, 1993). There are no class 1 soils in the study area; however, class 2 soils are present and worthy of conservation. Much of the study area contains soils of moderate agricultural value (class 3 – 4), and while not considered prime, they do have the potential to support agriculture. The location of gravel mining operations and pit quarries are also considered as locations of high resource value. Soil classes are grouped into the following three categories: Class 1 + 2 = High Agricultural Value, Class 3 - 4 = Medium Agricultural Value**,** Class 5 - 7 = Low/No Agricultural Value.

Historic sites, outdoor recreation areas, and scenic values are herein considered as sources of landscape amenity. The locations of cultural, historic and outdoor recreation sites are considered in this analysis. The existence of certain spatial relationships indicates scenic amenities important to humans. Views are shown to be important to humans, especially views of nature and water (Ambrey & Fleming, 2011). Three scenic value considerations, Views Created by Topography (Ambrey & Fleming, 2011), Scenic Highway Corridors (Anthea McGregor & Associates, 1999) and Scenic Water Resources (Northern Territory Government, 2011) assess these qualities of the study area.

Views created by topographic relief fall into the following two categories: Slopes > Or = 12% are rated high, Slopes < 12% are rated low. Views created by scenic highway corridors fall into the following two categories: areas with forest within 100’ of a highway buffer are rated high; areas with no forest in a 100’ of a highway buffer are rated low. Views rated by scenic water resources fall into the following two categories: areas within 100’ of streams and water bodies over 1ac are rated high**;** areas not within 100’ of streams or water bodies over 1ac are rated low.

Hazards and nuisance land uses. Environmental hazards and nuisances from natural and man-made sources are inventoried and assessed for their impact on adjacent land uses. These landscape characteristics are inventoried and buffers for adjacent land uses are determined. Two groups of factors (Hazards from Natural Sources and Hazards from Nuisance Land Uses) are included. These are not weighted to provide an index for suitability as in previous portions of the study; however, their inclusion provides a more inclusive understanding of development suitability in the study region.

Flooding and landslides are herein considered as sources of natural landscape hazards. Locations prone to landslides and flooding are assessed. Flooding is largely concentrated within the 100-year floodplain so these data are used to interpret the extent of flood-prone areas. Landslides occur in areas with a combination of steep slopes and disruptive land uses. Slopes of 12% and over, that are covered in a disruptive land use, are marked as landslide-prone. Hillsides that have had their natural cover removed are most susceptible to catastrophic failure (Muckel, 2004).

Airports, mining operations, factories and certain agricultural land uses are herein considered as sources of nuisance land uses. The locations of these features are inventoried, and an appropriate buffer radius is established for each. Factories are given the maximum buffer rating for hazardous industry as an initial rating for development considerations. However, the final value for this buffer will be determined on a case-by-case basis. “The width of buffer areas between potentially hazardous or offensive industries and non-compatible uses such as residential development will be dependent on the nature of the industry but should be of sufficient distance that adverse impacts are reduced to acceptable limits” (City of Lismore, 2007, p. 11-9). The buffer values for each nuisance land use are Airport: 4,000m**,** Extractive: 1,000m**,** Harmful Industry: 1,000m**,** and Poultry CAFO: 700m (City of Lismore, 2007)**.**

Intrinsic suitabilities for development. Intrinsic suitabilities for development have the potential to make or break development suitability determinations. Landscape characteristics are inventoried and assessed based on their ability to support development. Two groups of factors contributing specifically to development feasibility (Proximity to Infrastructure and Soil Limitations) are included in this assessment. These values are not weighted to provide an index for suitability as in previous portions of the study; however, their inclusion provides a more in-depth understanding of development suitability in the Clear Creek, Osage Creek and Headwaters watersheds.

Highly urbanized areas provide the best access to infrastructure. These areas are the most feasible for new development. Existing roadways contribute greatly to the feasibility of siting new development and do so based on use type. While interstates span great distances without providing new infrastructure, both arterial and county roads are sources of infrastructure for adjacent properties. New developments that take advantage of pre-existing infrastructure are much less costly to build (Bolan et al., 2002).

In order to create the proximity to infrastructure rating (see Figure 5), the study area is assessed based on values found in a Washington County, Minnesota study (Bolan et al., 2002). Existing urban areas are marked based on urban density; the densest areas afford extensive access to infrastructure. The most densely urbanized areas are buffered by one-quarter mile to show areas that have the highest access to all types of infrastructure. Roadways are buffered based on their use type to create an understanding of infrastructure proximity. Interstates are left unbuffered, while arterial roads are buffered by one-half mile and county roads are buffered by one-quarter mile. Areas outside these distinctions are considered to have limited access to infrastructure.

Soil and slope limitations contribute greatly to the feasibility of siting new development. The locations of waterlogged soils and slopes of over 12% are delineated in this analysis. Both of these factors make construction difficult and costly (Bolan et al., 2002).

Recommendations

Development Priority Areas

Based on the data presented in the previous analysis section, this portion of the study defines four classes of development priorities in the study area: priority preservation, cautious development, Smart Growth redevelopment, and Priority development areas (see Figure 6). All of the factors compiled in the previous analysis section are overlaid to determine these four distinctions. Each development classification is described and justified in this section.

Priority Preservation. Priority Preservation is the most restrictive planning overlay and therefore warrants the most thorough description. The analysis portion of this study shows that the headwaters area of the Illinois River is a fragile area under expanding development pressure. Preservation is not an option but a necessity for certain portions of the study area.

As determined in the first, second, and third portions of the analysis, water issues are of serious concern in the study area. The delicate condition of the hydrological cycle in the Ozark Plateau Region is framed primarily by the underlying karst topography. As determined in the first section of the analysis, karst areas are highly susceptible to water contamination (Department of the Interior, 2012). Since the population is expected to increase by 50% in certain portions of the study area in the next 10 years, surface and groundwater contamination issues are more important now than ever (Wiley, 2010).

The delineation of all bottomland areas (see Figure 1) is in need of priority preservation aids in protecting water quality while combining this interest with several other factors. As determined in the Surface Water Quality and Ground Water Quality portions of the analysis, forested bottomland acts as a sink for pollutants traveling in surface water and a filter for pollutants that would otherwise end up in ground water. Twelve digit watersheds with a small percentage of forested stream buffer have a higher susceptibility to surface and groundwater contamination (see Figures 2 and 3). To protect surface and ground water purity, these areas are to remain forested or to be reforested where currently associated with disturbance land cover types (Schueler, 1995).

The Wildlife Habitat section of the analysis determines the current condition and extent of species and habitat health in the study area. This analysis presents a fragmented picture of habitat with much room for improvement, and locates several jeopardized species in the bottomland areas (Arkansas Multi-Agency Wetland Planning Team, 2001; Arkansas Natural Heritage Commission, 2010). The highest quality forest habitats are included in the priority preservation area. Reforestation of bottomland increases habitat quality by providing a large continuous habitat corridor that is composed of a mix of habitat types (Dramstad et al., 1996).

Expanding forested areas of bottomland allows for the creation of new outdoor recreation sites and potentially provides the framework for a regional green network. As determined in the analysis, streams and water bodies have a high scenic amenity value (Northern Territory Government, 2011). Many of these resources are located in the bottomland area.

As has been shown, bottomland areas are determined by compiling many factors, however, the inclusion of 100-year floodplain data as determined by the Federal Emergency Management Agency (FEMA) creates the largest measurable area and forms the outline of the bottomland data in the analysis. FEMA delineates the floodplain based on the percentage of chance for annual flooding (Dinicola & Holmes, 2010). To inform the planning decisions of local jurisdictions, maps of these areas are available through an online service. All areas within the 100-year floodplain are justly associated with loss of life, property damage and higher insurance premiums (Dinicola & Holmes, 2010). As a further disincentive to development, soils in this area are typically hydrologically restricted and are rated poor for building due to the higher costs associated with construction (Soil Survey Division Staff, 1993).

As shown in the Human Factors portion of the analysis, there are no class 1 soils in the study area and a small quantity of class 2 soils. Preservation of this limited resource is essential for the future of Northwest Arkansas' agricultural productivity. "Fertile soils take thousands of years to develop. Creating them takes a combination of climate, geology, biology and good luck. So far, no one has found a way to manufacture them. Thus, productive agricultural land is a finite and irreplaceable natural resource" (American Farmland Trust, 2003, p. 01). Unfortunately, large portions of this resource are lost to development. A large percentage of the class 2 soils not located in the floodplain are in the eastern portion of the study area, precisely where the most intense development has occurred. Soil compaction is imminent in urbanized areas and cannot be feasibly reversed (Bolan et al., 2002). This fact requires the limited expansion of urban areas where these soils are affected.

Several qualities determined in the Human Factors portion of the analysis restrict development outright. Among these factors are areas prone to landslide hazards and areas adjacent to extractive or otherwise dangerous or offensive industry. These three categories are included in the priority preservation area to discourage development.

Cautious development. Of the land that passes the priority preservation test, a large portion is included in the cautious development planning overlay. The detailed analysis section of this study determines areas that are otherwise appropriate for development except for a few limiting factors.

As shown in the composite habitat quality index, forest patches in the study area are assessed based on their value for providing habitat. This composite rates forested areas as having high, medium or low values. Both medium and low value existing forest patches are included in the area recommended for cautious development. Medium and low quality areas of forest are already greatly impacted by surrounding land uses and provide reduced function as habitat (Dramstad et al., 1996). However, some protections are provided for these areas since there is currently an overall lack of forest patches in the study area. After some reforestation of priority preservation areas occurs, these lower quality areas may be opened for sensitive development. Preservation subdivisions offer a means for conserving forest while allowing development to occur.

Many of the areas considered for cautious development are limited by soil factors. Areas with hydrologically restricted or erosion-prone soils are rated for cautious development due to the costly extra steps that must be taken to build in these areas. Best Management Practices (BMPs) and Low Impact Development (LID) are necessary in these areas.

The locations of potentially hazardous industries are inventoried in the Human Factors section of the analysis. The buffer value included in this assessment is added to the total cautious development area. As described in the analysis, these areas are not restrictive to development outright but the type and scale of industry must be assessed before any new development can be planned within the buffer distance (City of Lismore, 2007).

Smart Growth redevelopment. Densification of existing urban areas is a major priority of this planning overlay. Since much of the developed area in Northwest Arkansas is of a low density, this is a reasonable priority. Much of the new growth projected for Northwest Arkansas could feasibly fit within the existing urban footprint (University of Arkansas Community Design Center, 2007). Smart Growth initiatives, mass transit and sprawl repair are ways of obtaining this goal.

Existing urban areas within the study area provide good potential for new development. As shown in Figure 5, most of the development in the study area is low density. This type of development is a likely contributor to the recent economic collapse, and the redevelopment and densification of these areas will likely be the path of future growth (Dunham-Jones & Williamson, 2009).

Priority development. Planning for priority development is a careful process requiring much forethought. To ensure a quality human environment and provide for sustainable economic growth, governments and planning agencies must follow regional environmental planning strategies. This portion of the study bases recommendations for priority development on key aspects of the analysis. Priority development areas are determined based on water, habitat and human factors in the study area.

Areas with the best access to infrastructure are included in the total priority development area (see Figure 5). These areas are based on the existing portions of the urban fabric that are categorized as high density, and seek to capitalize on existing built and social infrastructure. Priority development in these areas encourages the growth of a consistent urban core. Smart Growth practices are essential in these areas to ensure a sustainable outcome.

Conclusion

Regional business leaders have the ability to influence the direction of Northwest Arkansas' future, and they have made clear their understanding of the connections between a quality living environment and economic prosperity. The region's capability to attain a future of sustained economic success lies in the careful study of economic, social and ecological factors affecting the area. This scientific understanding of the region's unique characteristics must then be unified with current research in the field of thoughtful placemaking. By combining regional environmental analysis and Smart Growth land use planning, this study provides a clear path for the future growth and development of Northwest Arkansas.

References

Aller, L., Bennett, T., Lehr, J. H., Petty R. J., & Hackett, G. (1987). *DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings.* US EPA, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, EPA/600/2-85/0108.

Ambrey, C. L., & Fleming, C. M. (2011). Valuing scenic amenity using life satisfaction data. *Ecological Economics*, *72*, 106-115.

American Farmland Trust. (2003). *Why save farmland?* Washington, DC: Author.

Anthea McGregor & Associates, Daylor Consulting Group Incorporated, Land Use Incorporated, & Montachusett Regional Planning Commission. (1999). *Greater Gardner sustainable growth management plan.* Fitchburg, MA: Montachusett Regional Planning Commission.

Arkansas Multi-Agency Wetland Planning Team. (2001). *Functions and values of wetlands*. Retrieved from http://www.mawpt.org/wetlands/loss_gain.asp

Arkansas Natural Heritage Commission. (2010). *Arkansas endangered species*. Retrieved from http://www.naturalheritage.com/research-data/rarespecies-search.aspx

Bolan, R. S., Coleman, J., Discher, A., Kinney, J., Pitt, D. G., Thering, K., VanValkenburg, D., & Vossen, J. (2002). *Environmentally based regional smart growth planning and design*. Retrieved from http://www.crplanning.com/environplanninghandbook.htm

Beardsley, E., Bray, K., Camarillo, Y. C., Dye, W., Hobart, P., Hurley, C., McDonald, S. L., Mittal, A., Sasso, H. L., Shouse, B. N., Shulman, C. H., Turkett, J. W., & Wilmoth, G. (2008). *Report to congressional requesters on concentrated animal feeding operations: EPA needs more information and a clearly defined strategy to protect air and water quality from pollutants of concern*. Washington, DC: U.S. Government Accountability Office.

City of Lismore. (2007). *Buffer areas.* (*Chapter 11).* Retrieved from http://www.lismore.nsw.gov.au/page.asp?f=RES-MTD-23-17-78

Department of the Interior, & U.S. Geological Survey (2012). *What is karst?* Retrieved from http://water.usgs.gov/ogw/karst/pages/whatiskarst

Dinicola, K., & Holmes, Jr., R. R. (2010). *100-year flood–It's all about chance.* Retrieved from http://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210web.pdf

Dramstad, W. E., Olson, J. D., & Forman, R. T. T. (1996). *Landscape ecology principles in landscape architecture and land-use planning*. Cambridge, MA: Harvard University Graduate School of Design.

Dunham-Jones, E., & Williamson, J. (2009). *Retrofitting suburbia: Urban design solutions for redesigning suburbs*. Hoboken, NJ: John Wiley & Sons.

Gleeson, T., Smith, L., Moosdorf, N., Hartmann, J., Dürr, H. H., Manning, A. H., van Beek, L. P. H., & Jellinek, A. M. (2011). Mapping permeability over the surface of the earth. *Geophysical Research Letters*, *38*, L02401, doi:10.1029/2010GL045565

Haley, G. J., Harper, M. D., & Phillips, W. W. (1969). *Soil survey of Washington County, Arkansas.* Retrieved from http://soils.usda.gov/survey/online_surveys/arkansas/washington/manuscript-washington.pdf

Hawken, P. (2009). Natural capitalism. In T. Beatley & S. M. Wheeler (Eds.), *The sustainable urban development reader* (pp. 217-225). New York, NY: Routledge.

Jacobson, T. R. (1996). *Recovery plan for the cave crayfish.* Retrieved from http://ecos.fws.gov/docs/recovery_plan/961030.pdf

Market Street Services Incorporated. (2011). *Northwest Arkansas regional development strategy*. Retrieved from http://www.greaternorthwestarkansas.com/Welcome_files/NWA%20Regional%20Development%20Strategy.pdf

Minnesota Department of Natural Resources. (2003). *Methods – regionally significant ecological areas (terrestrial and wetland) assessment.* Retrieved from http://www.dnr.state.mn.us/rsea/ metro_methods.html

Muckel, G. B., National Soil Survey Center, & Natural Resources Conservation Service. (2004). *Understanding soil risks and hazards: Using soil survey to identify areas with risks and hazards to human life and property*. Lincoln, NE: USDA-Natural Resources Conservation Service.

Northern Territory Government. (2011). *Vegetation retention in the northern territory*. Retrieved from http://www.nretas.nt.gov.au/__data/assets/pdf_file/0020/5357/Veg_Retention_Factsheet_Native_vegetation_buffers_and_corridors.pdf

Randolph, J. (2004). *Environmental land use planning and management*. Washington, DC: Island Press.

Schueler, T. R. (1995). *Site planning for urban stream protection*. Washington, DC: Metropolitan Washington Council of Governments.

Soil Survey Division Staff. (1993). *Soil survey manual*. Washington, DC: USDA.

U.S. Fish and Wildlife Service. (2012). *Revised endangered species inventory.* Retrieved from http://www.fws.gov/arkansas-es/te_cty_list.html

University of Arkansas Community Design Center. (2007). *NWA rail: Visioning rail transit in Northwest Arkansas: Lifestyles and ecologies*. Fayetteville, AR: University of Arkansas Community Design Center.

White, S. M. (2000). Regulation of concentrated animal feeding operations: The legal context. *Land Use Law & Zoning Digest, 52*(2), 3-10.

Wiley, A., & UALR Institute for Economic Advancement. (2010). *County population projection by race and age group.* Retrieved from http://www.aiea.ualr.edu/ demographic-research/popprojb.html?vFips=05007&vRace=0